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ABSTRACT

This paper discusses the use of computers in urban schools and mathematics education as it relates to computer literacy, especially for black students. First, the importance of computer literacy as an entry to the technological workplace is emphasized and computer literacy is defined. Mathematics education is presented as an important step in achieving computer literacy. Research findings from other studies on access to and use of computers show that urban and Title I schools report heavy emphasis on computer-mediated remedial/basic skills instruction and suggest that computers are less accessible in predominantly minority elementary schools than in white schools. The lack of exposure of minority students to computers and information science is cited as a danger to their future in the workplace. Statistics show that black students fall far behind white students in mathematics education, but there are programs that have successfully challenged black students to achieve in mathematics. The Professional Development Program of the University of California at Berkeley is profiled. In conclusion, it is recommended that black students must be given access to computers; efforts must be substantially increased to help black students become computer literate rather than use computers for drill or remedial instruction; and steps must be taken to increase black students' proficiency in mathematics. Tables giving the data from studies are appended. (CG)

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MODERN TECHNOLOGY AND URBAN SCHOOLS

By

Robert E. Fullilove III

I. THE IMPORT OF COMPUTERS

> If the aircraft industry had evolved as spectacularly as the computer industry over the past 25 years, a Boeing 767 would cost $500 today, and it would circle the globe in 20 minutes on five gallons of fuel. Such performance would represent a rough analogue of reduction in cost, the increase in speed of operation and the decrease in energy consumption of computers. The cost of computer logic devices is falling at the rate of 40% per year. Computational speed has increased by a factor of 200 in 25 years. In the same period the cost, the energy consumption and the size of computers of comparable power have decreased by a factor of 10,000.[1]

The computer extends the user's senses and intellect. It is a medium of seemingly infinite capacities that is capable of becoming a laboratory, a simulated universe, a calculator, a library, a data storage/retrieval system, and a tutor. Personal computers are becoming increasingly available to the public. Powerful computer systems that would have cost hundreds of thousands of dollars 15 years ago can now be purchased for less than $500. As computers become more available, efforts to integrate their use into every phase of life are intensifying.[2]

Computers have the potential to totally reshape the socio-economic structure of this nation. Suddenly, a tool of tremendous power, whose limits have yet to be established, is being made available to millions of people. Those who wield its power most skillfully are likely to have an enormous advantage over those who are less skilled. It becomes critical to determine who is gaining access to computers and who will be wielding the power that they convey.

Concern about the impact of computers on society is not simply a domestic issue. In a world that is dominated by technology, computers promise to have a profound effect on the economic productivity of industrial nations. It is possible that in the near future, a nation's productivity will be proportional to the size of its computer literate workforce. Not surprisingly, increasing concern is being voiced in this country about whether America can maintain its position as a leading developer of technology in a world being deluged with computers.[3]

What is meant by "computer literacy?" One of the more thorough elaborations of the term was provided in the Practical Guide to Computers in Education:

1. Computer literate people would be able to program computers to achieve a wide variety of personal, academic, and vocational goals. They would be able to assess, understand,

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and if necessary, modify computer programs.

2. Computer literate people would be able to use a variety of preprogrammed computer applications in personal, academic, and professional contexts, and also understand the assumptions, values, and limitations inherent in particular pieces of software.

3. Computer literate people would understand the growing economic, social, and psychological impact of computers on individuals, on groups within our society, and on society as a whole.

4. Computer literate people would be able to make use of ideas from the world of computer programming and computer applications as part of their strategies for information retrieval, communication, and problem solving.[4]

The burden of producing a computer-literate workforce rests with the schools, but over the past decade, alarm about America's schools and the quality of its students has reached panic proportions. Numerous studies and commissions have documented a slow, steady decline in the academic achievement of American students. In A Nation at Risk: The Imperative for Educational Reform,[5] the National Commission on Excellence in Education concluded that the nation's future was imperiled by the poor quality of its students. In Science and Engineering Education for the 1980's and Beyond, the U.S. Department of Education and the National Science Foundation concluded:

> The role of science and technology is increasing throughout our society. In business, in government, in the military, in occupations and professions where it never before intruded, science is becoming a key to success. Today, people in a wide range of non-scientific and nonengineering occupations and professions must have a greater understanding of technology than at any time in history. Yet our educational system does not now provide such understanding.[6]

Similar sentiments were voiced by the National Science Teachers Association (NSTA). In Science-Technology-Society: Science Education for the 1980s[7], NSTA expressed grave concern over the deterioration of science and math instruction in the schools and called for broad based reforms that would result in the allocation of greater resources for science instruction. The Committee on Science, Engineering, and Public Policy, composed of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, in its examination of the problems confronting America's schools, proposed that such reform might be supported through increased use of computers.[8]

The Mathematics Association of America and numerous journals concerned with mathematics education (e.g., Computers in Mathematical Sciences Education) have been particularly concerned that students develop both familiarity with computers and with the mathematics concepts/skills to derive the maximum amount of potential from computers. To this end, the

National Assessment of Educational Progress (NAEP)--a national testing effort, conducted every five years since 1973 to measure the academic achievement of American school children--has attempted to determine what impact computers are having on the mathematics curriculum in the nation's elementary and secondary schools.

In the third mathematics assessment of NAEP in 1982 the proportion of students having access to a computer for learning mathematics had doubled the proportion reported in 1978, from 5% to 9.7%.

> Almost a fourth of the 13-year-olds and half of the 17-year-olds now say they have access to a computer in school. During the same period, the number of 17-year-old students who reported that they completed a course in computer science also doubled, as did the number who said they know how to program a computer.[9]

As computer use is growing in our schools, essential questions are being raised as to who is able to use them and what is being taught with them. One of the most important attempts to analyze the issue of equity in microcomputer use was conducted by John Lipkin of Litigation Support Services in 1983. In a paper entitled, "Equity and Microcomputer Use in Public Education,"[10] Lipkin concluded that the use and spread of technology in America has been consistent with Claus Lenk's "Matthew Effect" ("For whosoever hath, to him shall be given"). The Matthew Effect holds that the privileged members of society are the first to utilize technology--primarily since they are most able to afford its costs--and that their use of it ultimately increases their economic advantage over the less privileged members of the social order.

> If personal computers fulfill their potential to make learning more effective and to increase learning speed, the learners in the more advantaged strata will increase the education gap between themselves and those who do not have access to their personal computer. Higher income learners will become more competent learners, and to the extent that this increases productivity, their income differences will increase. (Nilles, 1980).[11]

If computers are conferring a disproportionate advantage on students in affluent schools, one might expect to see the following:

1. disadvantaged students would be less likely to have access to computers in their schools;
2. disadvantaged students with access to computers would have less hands-on exposure to them than more affluent students; and
3. disadvantaged students would be less likely to learn computer skills that would assist them to become skilled users.

II. COMPUTERS IN PUBLIC SCHOOLS

We examined two recent surveys to evaluate how computers were being used in the schools. The first was The Instructional Use of Computers in

Public Schools, Spring 1982.[12/] This survey, contracted by the U.S. Department of Education's National Center for Education Statistics, was not originally designed to compare affluent and non-affluent schools. However, it does permit a comparison of urban and suburban schools and of Title I and non-Title I schools (Title I schools are those that receive federal grants to create programs for children of low-income families). If the assumption is made that suburban schools are generally more affluent than urban or rural schools, or that non-Title I schools are more affluent than Title I schools, then some general assessment of the impact of computers on the schools of advantaged and disadvantaged students may be attempted.

In general the survey did not support the assertion that suburban schools or non-Title I schools are demonstrably more advantaged with respect to access to computers, but it did report important differences in the kind of instruction students were likely to receive in suburban and urban schools.

1. Computers were not significantly more accessible to suburban students than to rural or urban students.

Although urban schools in the survey were somewhat less likely to have computers (33% of all urban schools had computers) than suburban (37%) or rural schools (37%), urban schools boasted an average of 6.8 computers per school, as compared with 3.9 computers per suburban schools and 3.0 computers per rural school. (Table 1)

Urban schools with computers averaged only slightly fewer hours per computer (383.6) than suburban schools (397.9 hours) but made slightly more time available per student use (10.5 hours per student) than did rural (9.9 hours) or suburban schools (7.9 hours). In terms of availability and exposure to computers, therefore, urban schools appeared to be at no serious disadvantage when compared to rural and suburban schools and at a distinct advantage with respect to the number of computers per school and the number of hours of use provided per student. (Table 2)

2. Suburban children were only somewhat more likely to receive instruction in computer literacy and computer science than urban children, but urban children were much more likely to receive compensatory/remedial instruction than suburban children.

As indicated in Table 3, urban schools were much more likely to use microcomputers for compensatory/remedial and basic academic skills instruction (24%) than were rural (13%) or suburban schools (9%). However, urban schools spent approximately the same amount of time on computer literacy and on computer science instruction (31% and 21%, respectively) as rural (31% and 22%) schools and slightly less than suburban schools (37% and 25%). Moreover, urban schools spent considerably more time on computer science (47%) using computer terminals (as opposed to microcomputers) than did rural (26%) or suburban (29%) schools.

Urban schools did not differ significantly from rural or suburban schools with respect to the number of computer literate teachers per

school (8.8 "qualified teachers" per urban school as compared with 8.6 per suburban school and 5.8 per rural school). But urban schools were more likely to cite a need for more computers, a need for more and better compensatory/remedial courseware, and a need for more staff/community support than were rural or suburban schools.

3. Title I and non-Title I schools differed significantly in some aspects of their utilization of computers.

As indicated in Table 4, Title I schools (1) had slightly fewer computers for instruction (3.7 vs. 4.7); (2) slightly fewer students per computer (35.7 vs. 42.6), (3) significantly greater allocation of computer time for compensatory/remedial instruction (19% vs. 9%), and (4) significantly less time for computer literacy (25% vs. 40%) and computer science (16% vs. 31%) than non-Title I schools.

Though this survey does not suggest the existence of dramatic inequities in the exposure American school children are receiving to computers, it does suggest that students in urban schools and in Title I schools are receiving a great deal more computer-based remedial/compensatory instruction.

Several factors must be pointed out, however. The study made no attempt to evaluate the impact or the effectiveness of computer-based school instruction. Thus, it is not at all clear that the quality of the computer instruction in the schools is as uniformly distributed as the computers themselves appear to be. Further, "Urban" and "Title I" are broad categories, which, though used here to approximate the experience of minority schools, may significantly under report the differences.

It is clear that both urban and Title I schools were the schools most likely to report heavy emphasis on computer-mediated remedial/basic skills instruction in this survey, and that it is extremely likely, as will be demonstrated shortly, that minority students were the principal audience for such instruction.

III. COMPUTER USE IN THE SCHOOLS

Substantial support for this contention is provided by the second survey, conducted by the Center for Social Organization of Schools at Johns Hopkins University. School Uses of Microcomputers[13] surveyed 1,082 microcomputer-using elementary and secondary schools and attempted to determine how computer use in the schools varied according to the school's ethnic composition and the socio-economic status (SES) of its students. For purposes of analysis, schools in the survey were defined as either predominantly minority or predominantly white. Among predominantly white schools, schools were further classified as high SES (affluent), medium SES (middle income), or lowest SES (working class/poor). (It should be noted that fully two-thirds of the minority schools in the survey would have qualified as working class/poor, but for purposes of analysis, the distinction between white working class and minority schools was retained.)

1. **Computers were far less accessible in predominantly minority elementary schools than in predominantly white schools, irrespective of the socio-economic status of its students.**

An examination of computer use in the survey's elementary schools reveals stark differences between predominantly minority and predominantly white schools. As indicated in Table 5, computers were far less accessible in predominantly minority elementary schools than in white schools. In minority schools the ratio of students to computers was 233:1 as compared to a ratio 183:1 among all schools in the survey.

Of particular interest, however, were differences between white working class/poor elementary schools and predominantly minority elementary schools. These schools serve basically the same kinds of students and are confronting essentially the same set of educational problems. It is reasonable to assume, therefore, that they would report largely similar patterns of computer use. This was not the case, however.

In the main, white working class/poor schools made more computer time available to their students, exposed a larger portion of their student body to computers, and spent far more time exposing their best students to the computer than did either minority, middle income, or affluent schools.

Specifically, as indicated in Table 5, computer users in working class white elementary schools spent an average of 35 minutes per week in front of a computer, as compared with 24 minutes per user in affluent white schools, 22 minutes per user in middle income white schools, and 18 minutes per user in predominantly minority schools.

In addition to providing users with more time on the machine, working class/poor elementary schools also exposed a larger portion of their student body to computers. Working class poor schools exposed 35% of their students to computers, as compared with an average of 33% student exposure in middle income schools and 14% student exposure in predominantly minority schools. Only affluent elementary schools, with an average of 46% of the student body exposed to computers, did better.

2. **Minority and white elementary schools differed significantly with respect to the <u>type</u> of students exposed most extensively to computers and the <u>type of instruction</u> they received.**

Working class white schools appeared to be much more likely to expose their best students to computers. Approximately 51% of the working class white elementary schools used computers most extensively with their above average students while only 26% of the predominantly minority elementary schools provided computer activities for above average students. Predominantly minority schools, by contrast, were much more likely to report that their most extensive use of computers was with below average students (32%). Only 10% of the working class white schools, 12% of the middle income, and 16% of the affluent white elementary schools targeted computer uses for their below average students.

Working class white elementary schools were also significantly more likely to report that their most extensive instructional use of the computer was in programming/computer science (49%) and least likely to report extensive use of drill and practice instruction (9%). Minority schools were at the opposite end of the spectrum: they were more likely to report extensive use of drill and practice instruction (33% reported this as their most extensive instructional use of computers) and much less likely (10%) to report extensive instruction in programming/computer science than white schools.

These findings suggest important differences in the philosophy of computer use. At the elementary school level, at least, low income white schools are much more likely to use computers with their best students than are minority schools. They were much more likely to stress computer literacy and computer science and were less likely to use computers for basic skills/remedial education than were minority schools. Schools serving working class students were more likely to use their computer resources to create skilled computer users than were minority schools.

In many respects, these white working class schools have correctly anticipated the future trend in computer use in higher education. An increasing number of colleges and universities in the U.S., for example, will be requiring that students be computer literate upon graduation from college, and a number of schools -- among them, Massachusetts Institute of Technology -- will be requiring that their freshmen students enter college computer literate.

Marvin Marcus, professor of mathematics and vice chancellor for Research and Academic Development at the University of California, Santa Barbara, is one of a growing group of mathematicians who believe that computers will totally change our beliefs about what and how mathematics will be taught in our schools. "The point of view we take is that computing is part of mathematics [not the other inclusion] and that to use a computing machine creatively and effectively, one must understand certain basic mathematical concepts."[14]

These topics include: logic, sets, functions, function optimization, probability, and linear programming. These are the subjects that are at the foundation of the logic and syntax of computer programming. Many of the advances in computer science are due to discoveries made in these fields. In a computer-rich society, Marcus asserts, mastery of these topics will be at the core of a good foundation in mathematics and a part of the mathematics training of every student.

Marcus' text, Discrete Mathematics: A Computational Approach Using Basic, is a prime example of how the computer can be used by students to explore these subjects. The text is sold with a floppy disk that contains exercises and programs related to each chapter of the text. Students treat the computer as a laboratory to be used, for example, in the exploration of number theory or to master the principles of logic. Students frequently create or modify programs to perform experiments involving complex mathematical expressions. Use of the text in conjunction with a personal computer promotes skills in mathematics and in computer programming simultaneously.

Ideally, a course using this text would be offered to freshmen, perhaps as their first college math course. It could just as easily, however, be the terminal course in mathematics for high school seniors, anticipating deeper exploration of these topics in college. However, unless trends in the schools alter drastically, minority students are at extreme disadvantage in preparing for college mathematics at this level of complexity.

Mathematics, it should be pointed out, is not essential for computing, but proficiency in mathematics greatly expands the power of the individual user. As noted by the National Research Council's Science and Technology: A Five Year Outlook, "Computer science has been able to draw many of its most fundamental concepts ready made from mathematics. This fact has greatly accelerated the practical development of computing."[15]

As indicated in the Johns Hopkins' survey of computer uses in the schools, computer resources provided for minority students appear to be directed at improving their basic skills or at correcting a "learning deficiency" and not at having them become computer literate or computer competent. Conversely, working class/poor white youngsters appear much more likely to become skilled computer users if survey results are any hint of the future. To paraphrase Daniel Watt, it is all too likely that white youth are learning how to tell the computer what to do while black youth are being told what to do by the computer.[16]

Considering the level of mathematics skill of the average black student in American elementary and secondary schools, however, it is not surprising that so much computer time in minority schools is devoted to drill and practice or remedial/development work. The National Assessment of Educational Progress has consistently found blacks at all age-levels far below national norms in academic performance, particularly with respect to mathematics achievement.

"Results from the second mathematics assessment of the National Assessment of Educational Progress (NAEP) clearly document that serious inequities exist in the mathematics education of black and Hispanic students in the United States."[17] As indicated in Table 6A, the NAEP scores of blacks at ages 9, 13, and 17 lagged far behind those of whites and somewhat behind those of Hispanics both in 1973 and 1978, although the scores of blacks improved between 1973 and 1978, the gap between their scores and those of whites was not appreciably closed and appears to have persisted into the 1982 NAEP. (Table 6B)

> The improvement found for black and Hispanic students is important but not sufficient. Not only must educators continue to stress the basic skills, they must begin to build on these strengths and focus on the teaching of higher cognitive areas of understanding and application. Moreover, minorities should continue to enroll in advanced mathematics classes.[18]

As shown in Table 7, blacks also lagged significantly behind national averages with respect to mathematics courses completed by age 17. Only 7% of those blacks surveyed, for example, had taken trigonometry: this was almost one-half the proportion taken by 17-year-olds nationwide.

Since trigonometry is a pre-requisite for calculus in most American colleges, it appears evident that most black students in high school have seriously narrowed their career options in high school and have seriously restricted their chances for entering mathematics-based majors in college because of their failure to persist in mathematics in high school.

A study conducted by C. B. Marrett of the Wisconsin Center for Educational Research [19] provides a clearer picture of the distribution of blacks in mathematics courses in American high schools. In a national study that included 11,900 students, of whom there were roughly equal numbers of black and white students of both sexes, Marrett found that black males were least likely to be enrolled in advanced mathematics courses such as Algebra II and calculus, and most likely to be enrolled in general, non-college preparatory, mathematics.

As indicated in Table 8, blacks of both sexes were heavily concentrated in general mathematics and beginning algebra and very sparsely represented in algebra II and calculus. Well over three black students in four were in either beginning algebra or general math while fewer than five in every 100 were enrolled in calculus. Only 3% of the black males surveyed were in calculus (as compared with 4.6% of the black females and 10.1% of the white males).

These findings are hardly new. A paper, prepared in 1980 for the Ford Foundation, and entitled "Factors Affecting the Participation and Performance of Minorities in Mathematics", noted that blacks have historically lagged behind whites with respect to their academic achievement in mathematics and their enrollment in upper level mathematics courses in high school and in college.[20]

As indicated in Table 9, differences in the performance of blacks and non-blacks are evident in the College Entrance Examination Board's Scholastic Aptitude Test (SAT). The SAT is administered annually to more than one million college-bound students. In 1981 the mean SAT verbal score of black college-bound seniors was 332 out of a possible score of 800, and the mean math score was 362 out of a possible score of 800. Among whites these means were 442 and 483 respectively. Well over 75% of the verbal scores of blacks were below 400 (the bottom third of the score distribution). In contrast, only 34% of the verbal scores of whites were below 400. These differences in the relative performance of black and white SAT-takers have persisted for the past three decades.[21]

More dramatically, out of 75,425 black SAT-takers, only 24 earned SAT math scores in the top range between 750 and 800. Of these, 23 were men. Among students of Asian descent, however, fully 2% of all SAT-takers earned mathematics scores above 750. Significantly, the number of Asian SAT-takers was only one third that of black SAT-takers (29,675), but Asians placed thirty times the number of students at the top of score distribution (633 Asian students earned scores above 750 as compared with 23 blacks).

IV. PROGRAMS IN MATHEMATICS AND SCIENCE

Although the picture is a dismal one, there is hope. In examining the factors related to minority achievement, Morning, Mullins, and Penick note that a number of programs have been successful in promoting high achievement in mathematics among minority students at all levels of education. Among these were included the Special Elementary Education for the Disadvantaged (Project SEED — a program working with elementary school children in California); the Mathematics, Engineering, Science Achievement Program (MESA) also in California; the High School for Engineering Professions (HSEP) in Houston; the Accelerated Math Program (AMP) at Stevens Institute of Technology in New Jersey; and the Professional Development Program (PDP) of the University of California, Berkeley.[22] In addition to this sampling of programs are the Urban Project of the City University of New York and the Health Science Cluster Program of the University of Connecticut, both university sponsored programs that have attempted to increase the pool of minority high school students pursuing careers in mathematics and science-related fields.

One of the common themes running through the literature describing these programs is the belief that minority students must find the means to build upon their strengths as students. In too many instances, programs created for blacks and other minorities are concerned only with students' weaknesses and deficiencies. The programs cited here assume instead that students are competent and that the means must be found to have that competence demonstrated.

This program philosophy is particularly significant in light of survey findings of heavy use of computers for remedial instruction in schools that serve black students. There is considerable evidence that remedial approaches do not succeed in improving the mathematics performance of students but manage instead to convince black students that they are incapable of succeeding in mathematics.

Typically, remedial programs are structured around students' weaknesses. Diagnostic instruments are used to identify "learning deficiencies." Students are described as "disadvantaged" and continually reminded that they suffer in comparison to "traditional" students. In too many instances, this atmosphere promotes negative attitudes towards the study of mathematics and almost never promotes academic excellence.

The onward march of the computer revolution does not lie in any of the directions currently occupied by remedial mathematics. Students who are not being challenged to develop first-rate mathematics skills are at serious risk of being left behind. It is entirely possible that computers will develop to a point that makes it unnecessary for its user to possess any mathematics competence, but the trend, it has been suggested here, favors the students with strongly developed mathematics skills. Programs which focus too exclusively on "catching up" and not enough on excelling in mathematics are unlikely to provide students with competitive skills for a computer-dominated world.

The potential of blacks to achieve high levels of achievement in mathematics in a highly competitive academic environment is perhaps best dem-

onstrated by the Professional Development Program of the University of California at Berkeley. The school is recognized as one of the top public institutions of higher education in the country and is generally recognized as one of the leading science and technology institutions in the world.

Academically, Berkeley is highly competitive. The average SAT math score of its 1984 engineering freshmen was 698. To provide some measure of how all black SAT-takers nationally compare to Berkeley engineering students: roughly three quarters of the SAT math scores earned by blacks nationwide each year are below 400. The College of Engineering at UC Berkeley took no student in 1984 with scores below 400. Nationwide in 1981, 23 blacks earned SAT math scores above 750; 93 of Berkeley's freshmen engineers had scores at this level.

It is significant therefore, that black and Hispanic students participating in math/science workshops sponsored by Berkeley's PDP program have consistently out performed white and Asian American students in first year calculus since 1978. At Berkeley, students majoring in any science or mathematics-related discipline must complete at least one year of calculus satisfactorily in order to qualify for advanced coursework. First year calculus has traditionally been a graveyard for the hopes and aspirations of minority students, partially because the level of competition has been so rigorous. The success of PDP students in this course over the years has been impressive.

As indicated in Table 10, in the 1983-84 academic year, 63% of black and Hispanic students in PDP first year calculus workshops earned course grades of B or better. When compared with the performance of a random sample of 191 white and Asian students enrolled in the same course, PDP students earned significantly more grades above "B" and no grades of "D" or "F".

It is worth noting that slightly more than one-half of the PDP students in the sample had SAT scores below 600 while less than a third of the whites and Asians had scores at this level. When the SAT math score is held constant, exactly one-half of the PDP students with scores below 600 earned grades of "B" or better compared with 28% of the whites and Asian Americans in the sample with scores at this level. No PDP student, irrespective of SAT score, earned a grade below "C" while one-third of the whites and Asian-Americans in the sample with SAT scores below 600, and 17.6% of those with scores above 600 earned grades below "C".

As indicated in Table 11, the results of the 1983-84 PDP workshop program mirror those reported for blacks in the program since its inception in 1978. Slightly fewer than one-half of the PDP blacks in first year calculus courses earned grades of "B" or better during the period spanning 1978-82 with only two students out of 184 earning grades below "C". Significantly, the program seems to be particularly effective with students with SAT math scores below 600 where non-PDP blacks are at significant risk of failure.

The roots of PDP's success are complex. It is sponsored by Berkeley's faculty under the auspices of its Academic Senate. One of its founders,

Leon Henkin, is presently the chairman of Berkeley's Mathematics Department. One of Henkin's graduate students, Uri Treisman, designed the workshops. The program has been nurtured in an unusually rich mathematics environment. PDP is also an honors program. Students need not have been honors students in high school in order to join. Rather, the program requires of its participants that they pledge to work for honors-level grades in their classes. Participants also pledge to stay two to three assignments ahead of the class in their quest for high grades. This means that PDP students typically spend twice as much time on their studies as the average Berkeley freshman.

PDP has also pioneered in the use of learning groups in mathematics instruction. The use of learning groups involves organizing students into small clusters of four to six students. Members of these groups are taught to work cooperatively together on mathematics assignments. Students critique each other's work, they discuss their approaches to problems and they test each other's mastery of the material. The process of talking about their struggles with the subject matter strengthens their understanding and mastery of the concepts. Group work also assists students in their social adaptation to college and frequently becomes the center of the social networks that students form. Significantly, PDP students persist in the University at high rates -- approximately 80% persist to their senior year -- and membership in the workshop program is believed to have played a crucial role in their retention.

In sum, PDP appeals to well-motivated, high-achieving students. It sets high goals for them, demands hard work from them, but organizes this work in highly efficient fashion. It teaches students to work both independently and in groups, and in so doing, prepares students for the kind of work conditions that are frequently encountered in research laboratories and high technology think-tanks the world over.

But in many respects PDP's methods are not as significant as its accomplishments. At the heart of the program's success is the assumption that black students can succeed in mathematics if excellence is demanded of them and if means to achieve excellence are provided. The program demonstrates that blacks and Hispanics can compete equally with the nation's very best students. Its successes in a competitive academic environment suggest that similar successes can be achieved elsewhere.

V. SUMMARY AND CONCLUSIONS

PDP's successes have no small bearing on the use of computers in mathematics instruction in the nation's elementary and secondary schools. There is a danger, it has been suggested in this paper, in concentrating computer resources too heavily on remedial instruction. Moreover, there is a danger in failing to provide high-achieving students with sufficient opportunities to explore the computer's capabilities, particularly in mathematics.

Black students--and most particularly black males--are not persisting in high school mathematics and have effectively selected themselves out of the technological workforce before they have reached their seventeenth

birthday. Survey findings of computer uses in the schools suggest that if these students are being exposed to computers, it is more likely to be in drill and practice and/or remedial developmental applications and less likely to be in computer science or programming. Their peers in white schools--and particularly in working class/poor schools--are more likely, by contrast, to be in computer science and programming and less likely to be using the machine for remedial work. Here too, it has been suggested, blacks may be falling further behind in the race to become computer competent. The quest to have computers strengthen the academic skills of black students may prove to be costly if it means that blacks fail to use computers to become skilled users as well.

Black students are capable of high levels of academic achievement in mathematics but they must be challenged to do so. "Students should be assisted in developing realistic academic self-concepts, but they should be provided with alternatives that go beyond avoidance and dropping out as means of coping with difficult mathematics courses."[23] The computer is a medium that has the potential to provide just such an alternative, but there is some question as to whether that potential will be realized.

The computer is one of the few artifacts of Western Culture that is color blind. The efficiency of its operation and the quality of its output are entirely unrelated to the ethnicity of its user, but rather to the competence of its user. Blacks can achieve high levels of competence in computing as well as in mathematics. The resources of the nation's educational institutions must be directed to bringing this about.

Our analysis of computer use in the schools raises a number of disturbing questions. The first concerns access to computers in the schools--what can be done to insure that black students in our schools will have the same opportunity to work with computers that all students will have in 1985? The second concerns computer use in the schools. Are computers in black schools being used to help students master the intricacies of computer and information technology or are they being used essentially to drill remedial students? The third concerns the degree to which black students are receiving adequate academic preparation--particularly in mathematics--for computers. Are there steps that can be taken to increase the number of black students who persist in mathematics and who master the subject sufficiently well to become skilled computer users?

The evidence suggests that black schools are falling behind both in their use of computers and in their attempts to prepare students for jobs in a high-tech world. In order to remedy the situation, we recommend the following:

1. Efforts must be made to provide black students with access to computers, both in the schools and within the home. As computer prices continue to decline, they will come increasingly within reach of the average American family. Schools are frequently given discounts on computer prices, and a number of institutions have used their purchasing power to assist low-income families to obtain machines at

substantially reduced cost. Federal and state support for programs such as this would significantly increase both black computer ownership as well as the number of black students exposed to computers. Such a program would also have a significant, positive impact on the national economy by expanding the software market and by increasing the numbers of computer literate workers.

2. Computer literacy is rapidly becoming as critical as proficiency in reading, writing and computation. Substantially increased efforts to assist black students to become computer literate must be undertaken. Reports of heavy use of computers for remedial instruction are disturbing, and policies regarding computer-based instruction should be reassessed. Although computer assisted instruction may be useful in helping black students to overcome basic skills deficiencies, such instruction should not preclude efforts to teach students to become computer users as well.

   Current research suggests that the most powerful educational applications of computers are those that help students both to explore and master the computer's many resources and capabilities. Computers can stimulate intricate experiments in chemistry or physics -- they become, in effect, laboratories that students can use to test their understanding of the forces of nature. Computers can perform "thought experiments" that will assist students to explore the intricacies of mathematics and logic. These explorations not only strengthen students' mastery of these subjects, they will also strengthen students' ability to use computers skillfully and imaginatively. To date, the federal government has been the prime supporter of research and curriculum development for computer courseware, but, most experts agree, only the surface of this vastly promising field has been scratched. There is a general perception in the software industry that there are at best, only modest profits to be made in educational computing, and it becomes imperative that federal support for increased courseware development be continued and expanded. Such support, it is believed, will be instrumental in stimulating private investment in educational software production and marketing.

3. Black student attrition in high school mathematics has reached crisis proportions and must be addressed. There is little doubt that a failure to become mathematically literate will have disastrous consequences for these dropouts as they enter the nation's labor pool. We have noted here that proficiency in mathematics is absolutely critical in the development of comprehensive computing skills, and black students as a group are currently at a substantial disadvantage because of their poor math skills.

Programs such as Berkeley's Professional Development Program have demonstrated that black students can excell in mathematics. The tech-

niques of PDP, and programs like it, must be disseminated and adapted more broadly. Significantly, PDP's workshop program was developed with substantial assistance from the federal government, via a grant from the US Department of Education's Fund for the Improvement of Postsecondary Education. Programs with federal support have developed successful strategies for working with black math students at all levels of education.

There are no quick, easy solutions to the problems confronting black students in mathematics. But there are promising developments that deserve further, more extensive, exploration and development.

There is also no escaping the conclusion that the federal government has a critical role to play in bringing black students into the computer age. There is an old and very popular expression in the black community: "You got to bring money to get money." The truth of this adage is nowhere made clearer than in an examination of the issues we have raised here. Some federal investment must be made in the education and training of black youth for jobs in the technological workforce. Failure to do so will prove much more costly in the long run.

Although we have suggested that there is a need for increased federal support for educational computing, it is also clear that such support may not materialize. This will require redoubled state and local efforts to insure that computer literacy programs are created and maintained in all schools. A number of states, most notably Minnesota, have pioneered in the development of such efforts. Other states must follow their lead.

Educators have a share in these responsibilities also. They, too, must redouble their efforts to see that black students are exposed to a variety of educational computer applications, not just those that provide remedial drill and practice. Educators must shape the content of learning to match the current demands of technology. Black young people are threatened with exclusion from the worldwide technological revolution, but a partnership between educators and federal, state and local governments can and must be forged to remove this threat. As a nation, we cannot afford to do otherwise.

FOOTNOTES AND REFERENCES

1. Toong, H. D. and Gupta, A. "Personal Computers", Scientific American, December 1982, p. 86.

2. An excellent discussion of the current state of the art in computing may be found in the September 1984 issue of Scientific American. The entire issue is devoted to computer software and its uses.

3. See, for example, two publications from the National Research Council: Science and Technology A Five Year Outlook (Washington, D.C., 1979) and Outlook for Science and Technology The Next Five Years (San Francisco, 1982).

4. Coburn, Peter, et. al., Practical Guide to Computers in Education, (Reading, MA, 1982), p. 57.

5. A Nation At Risk: The Imperative for Educational Reform. A Report to the Nation and the Secretary of Education, by the National Commission on Excellence in Education. (Washington D.C., 1983).

6. Science and Engineering Education for the 1980's and Beyond. Prepared by the National Science Foundation and the Department of Education, Washington, D.C., 1980, p. 1.

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8. See their report, Information Technology in Precollege Education, Committee on Science, Engineering, and Public Policy, (Washington, D.C., 1984).

9. Carpenter, T.P. et.al., "Results of the Third NAEP Mathematics Assessment: Secondary School," Mathematics Teacher, December, 1983 p. 657.

10. Lipkin, J. P. Equity and Microcomputer Use in Public Education, Litigation Support Services (Washington, D.C., 1983).

11. From Nilles, J. A Technology Assessment of Personal Computers as quoted in Lipkin, op. cit., p. 11.

12. Data reported in this section were taken from National Center for Education Statistics, Instructional Use of Computers in Public Schools Spring 1982 (Washington, D.C., 1982).

13. Data reported in this section were taken from Center for Social Organization of Schools, Johns Hopkins University, School Uses of Microcomputers (ERIC #242-297, Washington D.C., 1983).

14. Marcus, Marvin, Discrete Mathematics: A Computational Approach Using BASIC, (Rockville, MD, 1983) p. x.

15. National Research Council, op. cit., p. 231.

16. The actual quote (taken from Lipkin, op. cit., p. 11) is "Affluent students are learning to tell the computer what to do, while less affluent students are learning to do what the computer tells them."

17. Anick, C. M. et. al., "Minorities and Mathematics: Results from the National Assessment of Educational Progress," Mathematics Teacher, October, 1981, p. 560.

18. Carpenter, op. cit., p. 658.

19. Marrett, C. B., Minority Females in High School Mathematics and Science (ERIC #231-611, Washington, D.C., 1982).

20. Morning, Carole, et.al., Factors Affecting the Participation and Performance of Minorities in Mathematics, (New York, NY, 1980).

21. Profiles, College-Bound Students, 1981 Admissions Testing Program of the College Board, (New York, 1982).

22. Morning, Carole, op. cit.

23. Ibid., p. 19.

TABLE 1

Availability of computer-based instruction in public schools during the 1981-82 school year, by school characteristics: United States, Spring 1982

School characteristics	All Schools	Schools providing computer-based instruction[1]		Number of Computer units[2] used for instruction	Average Number of computer units per school with computers
		Number	Percent[3]		
All schools	81,970	29,028	35	120,908	4.2
Instructional level:					
Elementary	50,800	11,364	22	26,258	2.3
Junior high	11,184	5,822	52	27,590	4.7
Senior high	14,113	10,445	74	62,290	6.0
Combined and other	5,874	1,396	24	4,769	3.4
Region:					
North Atlantic	16,398	6,433	39	27,941	4.3
Great Lakes and Plains	24,472	9,848	40	34,394	3.5
Southeast	18,301	4,967	27	13,607	2.7
West and Southwest	22,800	7,780	34	44,966	5.8
Metropolitan status:[4]					
Urban	19,857	6,490	33	43,932	6.8
Suburban	24,487	9,009	37	35,568	3.9
Rural	36,433	13,400	37	40,837	3.0

[1]With microcomputers, computer terminals, or both.

[2]Computer units include both microcomputers and computer terminals.

[3]Based on all schools in each category.

[4]Schools are classified as urban, suburban, or rural based on their ZIP codes. Urban schools have ZIP codes that comprise the central city portion of a Standard Metropolitan Statistical Area (SMSA) as defined by the Census Bureau. Suburban schools lie within an SMSA, but outside the central city. Rural schools lie outside SMSA's. Information on metropolitan status was not available for an estimated 1,183 schools, 129 of which provided computer-based education. These schools were excluded from the counts and percentages for metropolitan status.

Note.--Numbers may not add to totals because of rounding.

Source: Instructional Use of Computers in Public Schools Spring 1982 (NCES, 1982) includes Tables 1-4

TABLE 2

Extent of computer usage for instruction in schools with computers, by school characteristics: United States, Spring 1982

School characteristics	Schools providing computer based education[1]	Average number of hours per computer in 1981-82	Average number of students per computer	Average number of hours per student in 1981-82
All schools	29,028	360.7	39.1	9.2
Instructional level:				
Elementary	11,364	399.3	65.5	6.1
Junior high	5,822	323.5	43.7	7.4
Senior high	10,445	367.9	27.9	13.2
Combined and other	1,396	249.9	12.7	19.8
Region:				
North Atlantic	6,433	336.8	37.5	9.0
Great Lakes and Plains	9,848	480.7	39.1	12.3
Southeast	4,967	282.9	42.9	6.6
West and Southwest	7,780	305.6	38.8	7.9
Metropolitan status:[2]				
Urban	6,490	383.6	36.4	10.5
Suburban	9,009	397.9	50.5	7.9
Rural	13,400	308.1	31.1	9.9

[1]With microcomputers, computer terminals, or both. Numbers may not add to total because of rounding.

[2]Information on metropolitan status was not available for an estimated 129 schools providing computer-based education. These schools have not been included in the estimates for metropolitan status.

TABLE 3

Major allocation of computer time for instruction, by type of computer unit and school characteristics: United States, Spring 1982

School characteristics	Schools providing computer based education	Instructional purpose[1]				
		Compensatory/ remedial	Basic academic skills	Learning enrichment	Computer literacy	Computer science
1	2	3	4	5	6	7
Microcomputers		(In percents of column 2)				
All schools	27,501	14	19	19	33	23
Instructional level:						
Elementary	11,050	18	29	21	29	7
Junior high	5,774	20	11	19	30	10
Senior high	9,504	6	12	18	39	49
Combined and other	1,173	19	6	4	34	15
Region:						
North Atlantic	6,213	13	15	11	30	17
Great Lakes and Plains	9,224	14	20	15	31	23
Southeast	4,620	12	12	29	40	25
West and Southwest	7,444	17	24	24	33	25
Metropolitan status:[2]						
Urban	5,887	24	26	17	31	21
Suburban	8,610	9	12	20	37	25
Rural	12,874	13	19	19	31	22
Computer terminals						
All schools	5,898	12	13	24	22	34
Instructional level:						
Elementary	958	23	20	28	0	0
Junior high	978	28	10	23	23	14
Senior high	3,620	6	13	21	28	47
Combined and other	343	0	0	50	15	45
Region:						
North Atlantic	1,273	7	0	20	14	51
Great Lakes and Plains	2,319	8	5	27	37	27
Southeast	773	0	37	16	13	30
West and Southwest	1,553	28	22	28	12	33
Metropolitan status:[2]						
Urban	2,034	20	4	30	24	47
Suburban	1,827	2	9	20	24	29
Rural	1,999	12	25	23	20	26

[1]Respondents could indicate zero, one, or more than one major instructional purpose.

[2]Information on metropolitan status was not available for an estimated 129 schools providing computer-based education (excluded from this analysis).

TABLE 4

Comparison of the Availability of Computer-Based Education, Usage, and Needs in Title I and Non-Title I Schools: United States, Spring 1982

Item	Title I schools	Non-Title I schools
All schools	44,164	36,901
Schools with either microcomputers or terminals for instruction	15,268	13,303
Number of microcomputers and terminals for instruction	56,404	62,505
In schools with computers:		
Average number of computer units for instruction per school	3.7	4.7
Average number of students per computer	35.7	42.6
Average number of hours per computer in 1981-82	331.8	392.4
Average number of hours per student in 1981-82	9.3	9.2
Percent of schools with microcomputers indicating major allocation of microcomputers time for:[1]		
Compensatory/remedial	19	9
Basic academic skills	20	18
Learning enrichment	17	21
Computer literacy	25	40
Computer science	16	31
Percent of schools with microcomputers indicating major need for courseware for:[1]		
Compensatory/remedial	44	32
Basic academic skills	41	33
Learning enrichment	42	49
Computer literacy	42	50
Percent of all schools indicating the following as major needs for initiating or improving computer-based education:[1]		
Startup assistance	47	51
Qualified teachers	48	53
More microcomputers	60	68
Suitable courseware	60	64
Staff/community support	42	40

[1]Respondents could indicate zero, one, or more than one major category for this question.

Note.--Information on Title I status was not available for an estimated 905 schools (excluded from this analysis).

TABLE 5

HOW RACE AND SES* ARE RELATED TO MICROCOMPUTER OWNERSHIP AND USE (UNIVERSE: ELEMENTARY SCHOOLS WITH ONE OR MORE MICROCOMPUTERS)

	WHITE HIGH SES	WHITE MED SES	WHITE LOWEST SES	PRED. MINOR.	ALL SCHOOLS
MEDIUM RATIO STU/COMPUTERS	155:1	183:1	192:1	233:1	183:1
MEDIUM % OF USE/WEEK	24%	22%	12%	13%	16%
MEDIUM NUMBER MINUTES/USER	24	22	35	18	23
% OF SCHOOL COMPUTER EXPOSURE	46%	33%	35%	14%	35%

PATTERNS OF USE WITHIN THE SCHOOLS

	WHITE HIGH SES	WHITE MED SES	WHITE LOWEST SES	PRED. MINOR.	ALL SCHOOLS
% REPORTING INTENSIVE USE OF MICRO DRILL AND PRACTICE	13%	18%	9%	33%	18%
INSTRUCTION IN PROGRAMMING	21%	17%	49%	10%	23%
WITH: ABOVE AVERAGE STUDENTS	24%	30%	51%	26%	31%
AVERAGE STUDENTS	14%	9%	22%	12%	12%
BELOW AVERAGE	16%	12%	10%	32%	14%

Source: School Uses of Microcomputers
(Johns Hopkins University/Washington DC, 1983)
*Socio-economic status

TABLE 6-A

Change Results

	Average Percent Correct for All Change Exercises Administered					
	Age 9		Age 13		Age 17	
	1973	1978	1973	1978	1973	1978
Nation	38	37	53	51	52	48
Black	23	26	32	32	34	31
Hispanic	28	29	40	37	38	36

Source: MATHEMATICS TEACHER
October, 1981

TABLE 6B

Achievement by Course Background for 17-Year-Olds (NAEP: 1978)

	Mean Percent Correct				
Level	All 17-Year-Olds	Less than Algebra I	Algebra I	Geometry	Algebra 2
Skills					
Nation	59	42	53	61	70
Black	41	33	42	47	52
Understanding					
Nation	58	42	51	62	67
Black	41	34	40	47	48
Applications					
Nation	44	29	36	46	52
Black	26	21	25	30	30

TABLE 7

Mean Changes in Performance for White, Black, and Hispanic Students

	Age 9 Average Performance			Age 13 Average Performance			Age 17 Average Performance		
	1978	1982	Change Perf.	1978	1982	Change Perf.	1978	1982	Change Perf.
Nation	55.4%	56.4%	1.0%	56.6%	60.5%	3.9%*	60.4%	60.2%	0.2%
White	58.1	58.8	0.7	59.9	63.1	3.2*	63.2	63.1	0.2%
Black	43.1	2.1	45.2	41.7	48.2	6.5*	43.7	45.0	1.3%
Hispanic	46.6	47.7	1.1	45.4	51.9	6.5	48.5	49.4	0.9%

*Change is significant at the .05 level.
Source: Mathematics Teacher (December, 1983)

TABLE 8

DISTRIBUTION OF MATH COURSES WITHIN COURSE AND WITHIN GROUP BY RACE AND SEX[a]

COURSE	GROUP				
	BLACK FEMALES (%)	BLACK MALES (%)	WHITE FEMALES (%)	WHITE MALES (%)	TOTALS
GENERAL MATH					
WITHIN COURSE 100%	29.7	35.3	16.0	19.0	100%
WITHIN GROUP (N=4236	43.8	52.9	22.7	25.0	
BEGIN. ALGEBRA					
WITHIN COURSE 100%	27.5	23.9	22.9	23.8	100%
WITHIN GROUP (N=2666)	25.5	22.5	20.4	21.4	
GEOMETRY					
WITHIN COURSE 100%	18.4	14.4	34.6	32.5	100%
WITHIN GROUP (N=1999)	12.8	10.2	23.1	20.2	

TABLE 8
(Continued)

COURSE	GROUP				
	BLACK FEMALES (%)	BLACK MALES (%)	WHITE FEMALES (%)	WHITE MALES (%)	TOTALS
OTHER INTERMED COURSE					
WITHIN COURSE 100%	24.6	23.0	29.7	22.6	100%
WITHIN GROUP (N=547)	4.7	4.4	5.0	4.1	
WITHIN COURSE 100%	15.6	11.5	37.2	35.8	100%
WITHIN GROUP (N=1630)	8.8	6.6	20.2	18.2	
CALCUL. OTHER ADVANCED COURSES					
WITHIN COURSE 100%	16.0	10.1	34.4	39.5	100%
WITHIN GROUP (N=821)	4.6	2.9	9.4	10.1	
	(N=2824)	(N=2870)	(N=2992)	(N=3213)	

Source: Minority Females in High School Mathematics (ERIC #231-611, Washington DC, 1982)

TABLE 9

SAT-TAKERS IN THE UNITED STATES, 1981

VERBAL SAT SCORES
(N=430,005)

RACE OF SAT-TAKERS	SCORE INTERVALS 200-399 (%)	400-599 (%)	600-800 (%)
BLACKS	76	23	1
CHICANOS	62	36	2
PUERTO RICANS	65	32	3
WHITES	34	58	8

MATH SAT SCORES
(N=912,683)

	200-399 (%)	400-599 (%)	600-800 (%)
BLACKS	69	29	2
CHICANOS	46	48	4
PUERTO RICANS	55	40	5
WHITES	22	60	18

SOURCE: PROFILES, COLLEGE-BOUND SENIORS, 1981
College Board (New York, NY, 1982)

TABLE 10

PROFESSIONAL DEVELOPMENT PROGRAM FIRST-YEAR CALCULUS 1983-84

FALL MATH IA GRADES BY RACE, MEMBERSHIP IN WORKSHOP PROGRAM

	WHITES/ ASIANS N=191 (%)	NONWORKSHOP BLACKS/HISP. N=44 (%)	PDP WORKSHOP BLACKS/HISP. N=19 (%)
A & B	52.4	29.5	63.1
C	25.1	25.0	36.8
D & F	22.5	45.5	0.0

FALL MATH IA GRADES FOR STUDENTS WITH SAT MATH SCORES BETWEEN 400-600 AND 600-800 BY RACE AND MEMBERSHIP IN A WORKSHOP PROGRAM

(SAT MATH SCORE BETWEEN 400-600)

	WHITES/ ASIANS N=57 (%)	NONWORKSHOP BLACKS/HISP. N=26 (%)	PDP WORKSHOP BLACKS/HISP. N=10 (%)
A & B	23.1	18.2	50.0
C	38.6	30.8	50.0
D & F	33.3	50.0	0.0

(SAT MATH SCORE BETWEEN 600-800)

	WHITES/ ASIANS N=131 (%)	NONWORKSHOP BLACKS/HISP. N=11 (%)	PDP WORKSHOP BLACKS/HISP. N=9 (%)
A & B	62.6	54.6	77.7
C	19.8	9.1	22.2
D & F	17.6	36.4	0.0

SOURCE: Professional Development Program (UC Berkeley, 1984)

TABLE 11

DISTRIBUTION OF FIRST-YEAR CALCULUS GRADES OF PDP STUDENTS, 1978-82

	PDP BLACKS 1978-82 (N=184) (%)	ALL PDP 1978-82* (N=28) (%)
GRADES		
A & B	63.7	58.9
C	44.6	38.9
D & F	1.1	2.1

FIRST-YEAR CALCULUS GRADES OF PDP WITH SAT MATH SCORED BETWEEN 400-600

	BLACKS (N=122) (%)	ALL PDP (N=182) (%)
A & B	52.5	48.4
C	45.4	50.8
D & F	2.2	.8

SOURCE: Professional Development Program
*Blacks are double-counted in these totals.